INFRASTRUCTURE INTERDEPENDENCY ASSESSMENTS: INTERDISCIPLINARY RESEARCH AND RISK ANALYSIS AT SANDIA NATIONAL LABORATORIES

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The importance and nature of interdisciplinary analyses is reflected in the research conducted at the national laboratories, many (if not most) of which require experts from multiple fields. The degree of collaboration required to complete these interdisciplinary analyses tends to be greater than for analyses performed at universities where the focus is on measuring individual learning, achievement and research. However, the distinction between interdisciplinary national laboratory and university research should be obscured as system complexity increases and we continue to develop and expand our capacity for abstract thought, refine our understanding of system function and evolution, and attempt to improve or modify existing complex and interdependent systems.

Much of the work at the national laboratories involves risk assessment. Risk assessment by its nature, defining consequences (e.g., health effects, mission failure, expenses) and their probabilities (or likelihood), requires interdisciplinary analyses. Applying risk assessment techniques to specific problems or subject matter (e.g., mechanical engineering, environmental science, and communications) increases the areas of expertise necessary to evaluate and solve those problems. Sandia National Laboratories' (SNL's) history of developing and applying risk based assessment methodologies to a wide range of problems, includes: nuclear power plant physical security, critical infrastructure surety, probabilistic performance assessments for radioactive waste disposal, information system vulnerability analysis and infrastructure interdependency assessments[1-7]. SNL's risk-based decision and assessment framework has been implemented by the Nuclear Regulatory Commission for site license termination analyses and is easily adapted to any complex decision and analysis process.[8] No matter the application, uncertainties must be incorporated at the beginning of the analysis in order to optimize the data collection/modeling/mitigation decision process.

Understanding and quantifying uncertainties and system behavior requires specialists from multiple fields. In the case of infrastructure interdependency analyses, experts on electric power generation and transmission, water distribution systems, hydrogeology, communications systems, economics, meteorology, transportation systems, regulations, emergency services and petroleum engineering, work with government and industry specialists to evaluate the uncertainties and model system (or process) dependencies and the potential effects of infrastructure interdependencies on that system. Simulation tools linking process models to infrastructure models are used in these analyses. Examples of these multidisciplinary analysis tools include dynamic systems models with infrastructure dependencies and interdependencies, agent-based micro-economic simulations with multiple, interdependent infrastructures and advanced interdependencies process modeling.

In each system assessment the perceived significance of the identified risks or vulnerabilities depends on the viewer's scale of concern (e.g., individual business, industry, state, nation) and the metrics of the analysis (economic criteria, performance thresholds, timetable, likelihood). Due to the scope and complexity of the infrastructure interdependency problem, SNL researchers use several types of modeling and assessment tools. Agent-based models of interdependent infrastructure transactions are used to simulate micro-economic effects of infrastructure disruptions to identify potential cascading impacts and economic consequences. Dynamic system models are used to evaluate model and parameter uncertainties, identify physical limitations and potential macro-economic effects of infrastructure disruptions as a function of system conditions. These modeling tools are used to gain a better understanding of infrastructure interdependencies, systems sensitivities, and the potential changes in those sensitivities as the systems evolve. This knowledge can be used to improve monitoring system designs, system models and analysis methods and provide the technical justification for information sharing and warning systems, planning system improvements, and designing more effective regulations and policies.

We are just beginning these modeling studies and there are challenges that are ideal for collaboration between the university, national laboratory and industry/utility researchers. Potential topics for collaborative research include identifying and evaluating national, state and local policy options; developing models for sustainable development and community planning; predicting system evolution and potential impacts; refining existing systems models and assessments to include interdependencies and uncertainties; evaluating potential micro-economic impacts of infrastructure disruptions, policies and system aging; and evaluating and resolving model scaling issues. In addition to the potential for collaborative research, education programs that reward interdisciplinary research are of value because the nation's research laboratories and industry require and hire researchers that are capable of performing interdisciplinary analyses.

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